N80Y

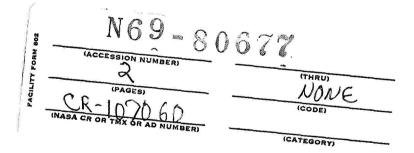
Reprinted from IEEE Transactions on Electronic Computers, Vol. EC-15, No. 5, p. 799, October 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## Technical Report 32-1040

# The Self-Diagnosability of a Computer

Narsingh Deo



This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

### The Self-Diagnosability of a Computer

#### NARSINGH DEO

Abstract-Maximum capability for self-diagnosis with minimum additional hardware is the goal of every designer of a general purpose computer today. A yardstick with which the self-diagnosability of a system can be measured is proposed.

A self-diagnosable computer can be described as a system consisting of two interconnected but independent machines: the main processor  $M_1$  and a much smaller machine  $M_2$  (about 5 to 10 percent of the size of  $M_1$ ), which is capable of (programmatically) detecting and locating a fault in  $M_1$ . This fault location should be pinpointed within a small number of replaceable modules (integrated circuit chips, parallel-plate packages, or printed circuit cards) [1], [2].

The most commonly employed technique for diagnosis is to prepare a list of a complete set of tests  $T = \{T_1, T_2, \dots, T_n\}$  such that every failure in the system will cause one or more of these tests to fail [2]-[4]. Let the set  $F = \{F_1, F_2, \dots, F_m\}$  represent all possible single failure cases in the system. By taking the intersection of the sets of suspects for the failing test cases  $T_{i1}$ ,  $T_{i2}$ ,  $\cdots$ ,  $T_{ir}$  one arrives at a fault  $F_i$ . Let  $k_1, k_2, \cdots, k_m$  be the number of suspected modules under the faults  $F_1, F_2, \dots, F_m$ , respectively. In other words, during the Maintenance Routine [3] run, if tests  $T_{ii}$ ,  $T_{i2}, \cdots, T_{ir}$  fail, and the rest of the tests pass, then from a look-up table we arrive at the conclusion that fault  $F_i$  has occurred, and in order to correct this fault  $F_i$  we have to either replace  $k_i$  number of modules or examine each of these  $k_i$  modules by some other means and replace the bad one.

Clearly then, if N = total number of modules used in the machine,

$$\sum_{i=1}^{m} k_i \ge N. \tag{1}$$

Let  $p_i$  be the probability of occurrence of failure  $F_i$ , for  $i=1, 2, \cdots$ , m. Then assuming that at a given instance exactly one fault has occurred.

$$\sum_{i=1}^{m} p_i = 1. \tag{2}$$

Number  $R_i = 1/k_i$  is an indicator of the efficiency with which fault  $F_i$  can be repaired. The diagnostic efficiency of the entire system can be represented by

$$R = \frac{1}{\sum_{i=1}^{m} k_i p_i}$$
 (3)

This number R can be called the "resolution" of the entire system. The comparative figure of merit of a diagnostic subsystem is then

$$\frac{R}{\cos t}$$
 (4)

where the cost includes the cost of hardware in  $M_2$ , of software, of development, and of running time of the maintenance routine.

If the maintenance routine only detects, and does not locate a fault, then R assumes its minimum possible value

$$R_{\min} = \frac{1}{N} \cdot \tag{5}$$

This implies that one has to examine all N modules of the machine to locate the faulty module.

The resolution R is maximum when every failure can be traced down exactly to one module, i.e.  $k_i = 1$ , for  $1 \le i \le n$ . Then from (3), resolution becomes

$$R_{\text{max}} = \frac{1}{\sum_{i=1}^{m} p_i} = 1. \tag{6}$$

If all modules are assumed to have equal probability of failure, then the probability of occurrence of failure  $F_i$  is given by

$$p_i = \frac{k_i}{\sum_{i=1}^{m} k_i} \tag{7}$$

and the resolution of the machine by substituting (7) in (3) turns out to be

$$R_{e} = \frac{\sum_{i=1}^{m} k_{i}}{\sum_{i=1}^{m} k_{i}^{2}} \cdot$$
 (8)

In absence of any statistical data available on the probability of various failures, (8) would be a good index of the diagnosability of a system.

In the author's opinion the resolution in (8) is a very important figure in the specification of any machine with diagnostic capability. The manufacturer should specify it, and the customer should ask for it. As discussed above, in general, Re will have a value between 1 and 1/N.

#### REFERENCES

- R. E. Forbes, D. H. Rutherford, C. B. Stieglitz, and L. H. Tung, "A self-diagnosable computer," Proc. F.J.C.C., vol. 27, pp. 1073-1086, November 1965.
   K. Malig and E. L. Allen, "A computer organization and programming system for automated maintenance," IEEE Trans. on Electronic Computers, vol. EC-12, pp. 887-895, December 1963.
   R. S. Ledley, Digital Computer and Control Engineering. New York: McGraw-Hill, 1960, pp. 135-139.
   J. M. Galey, R. E. Norby, and J. P. Roth, "Techniques for the diagnosis of switching circuit failure," IEEE Trans. on Communication and Electronics, vol. 83, pp. 509-514, September 1964.

Manuscript received June 2, 1966.
The author is with Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. He was formerly with Burroughs Corporation, Pasadena, Calif.

Reprinted from IEEE TRANSACTIONS ON ELECTRONIC COMPUTERS Volume EC-15, Number 5, October, 1966

P. 799 COPYRIGHT © 1966-THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. PRINTED IN THE U.S.A.